

SAM R. HOOVER, LENORE B. JASEWICZ, and NADOR PORGES  
*Eastern Utilization Research Branch, Agricultural Research Service,  
U. S. D. A. - Philadelphia, Penna*

**AEROBIC PROCESS FOR TREATMENT OF DAIRY  
WASTES**

*Offprint from Volume II of the XIVth International Dairy Congress Proceedings.*

Pure water is needed by both farm and city people. In the United States, the control of stream pollution is primarily a function of the state governments, many of which have active pollution-control programs. The problem affects the dairy industry seriously because the waste waters from milk processing plants contain the residual milk washed from cans, coolers, bottling machines, pumps, etc., plus that lost by leaking connections, spilling, or occasional overfilling of tanks and bottles. Losses of about one per cent of the milk handled are considered reasonable operating losses in the industry. The amount of the milk lost, therefore, is roughly proportional to the amount processed, except where poor plant management allows excessive loss of milk solids. The polluting effect of the waste from many American market milk plants is also much greater than the figure cited above due to the whey from cottage cheese, which may contribute more milk solids than the normal operating wastes. These wastes are diluted with the water used in the plant. The concentration of milk solids in the effluent is about 0.1 per cent, or 1000 ppm. Although too dilute for possible recovery of the organic matter, they are about five times as concentrated a pollutant as domestic sewage.

Because all branches of the dairy industry needed better methods of waste treatment, the U. S. Department of Agriculture started research on this problem in 1947. The aerobic processes were investigated because of the high oxygen demand of the waste and the high rate of growth of bacteria on media containing milk. Basic studies made of the oxidation of the mixed aerobic culture that grows in aerated milk waste indicated that a rapid aerobic process could be developed. Determinations were made of the

amount and chemical makeup of the cell tissue produced, the amount of oxygen required, the effect of temperature, and oxygen tension. In this way, the necessary facts for pilot-plant engineering studies were established. The biochemical results were as follows:

1. The rate of oxygen uptake by a growing culture containing 1000 mg. of cells, with adequate nutrients, is at least 140 mg. of oxygen per hour. This value is about 20 times that of the saturation pressure of oxygen in water, thus requiring an extremely efficient air supply to maintain aerobic conditions.
2. The minimum concentration of dissolved oxygen needed for maximum rate of growth is 0.3 - 0.5 mg. per liter (ppm.).
3. The total oxygen required for the complete oxidative combustion of one mg. of milk solids is 1.2 mg.
4. Three-eighths (37.5%) of the total oxygen requirement is used during the rapid-growth phase. The remaining five-eighths (62.5%) is synthesized into cell tissue. The only other oxidation products are carbon dioxide and water (1).
5. After cell synthesis is complete, the rate of auto-oxidation (endogenous respiration) falls to about one-tenth or less the rate of oxygen consumption during growth (2).
6. The rate of removal of organic nutrients during the rapid growth phase is approximately ten times that of the rate of oxidation.
7. These nutrients are stored as polysaccharide constituents of the cells. The polysaccharides are oxidized during growth of the cells, and the rate of oxidation remains high until these storage carbohydrates are consumed. The maximum storage capacity of the cells is about 50 per cent. i. e., one mg. of cells can store 0.5 mg. reserve carbohydrate.
8. Complete balanced equations for the growth and endogenous respiration reactions were formulated (1,3).
9. The rate of growth of the culture at 20°C. is about 65 per cent of the rate at 30°C., while at 10°C., it is 30 per cent. In other experiments, it was shown cultures can be acclimatized or adapted to a temperature of 20° so that a relatively higher rate can be obtained, perhaps 80 per cent of the rate 30°C.

On the basis of these laboratory studies summarized in (4), a research contract was established for pilot-plant development of a full scale treatment process. This work was done at the Pennsylvania State University by Professor R. Rupert Kountz and his assistants. A series of excellent engineering studies confirmed and extended the laboratory results.

On the basis of the laboratory and pilot-plant work, a « fill-and-draw » operation was proposed to the industry. The schedule of operation in a great many American milk processing plants is such that nearly all the wastes are released during the morning and early afternoon, over a period of about six hours. Under these circumstances, continuous flow systems patterned after municipal sewage practice cannot operate in a continuous manner, since the treatment plant effluent can only flow while it is receiving effluent from the processing plant. It is obviously undesirable to have the plant releasing its effluent over the short period in which it is receiving the waste. Any large « spill » or uneven flow would tend to pass through the plant untreated. If the wastes can be contained in the plant until night, a longer period of aeration is available, and a fully-treated waste can be released. A second advantage is that the aeration tank serves as a settling tank. The air supply is shut off soon after the dairy operations cease, the sludge or cell mass allowed to settle, and the supernatant released.

The first industrial waste treatment plant designed on the recommended system went into operation in April 1954 and has operated successfully since then (5). At present there are nine plants in operation, all directly based on the work at Pennsylvania State University; and many others have been built in which some or all the recommendations of Professor Kountz have been the basis for the design.

Essential features of the recommended design are an adequate supply of dissolved oxygen within the daily aeration period and a high concentration of active bacterial cells. The most successful aeration device tested so far in the contract research has been a water-operated venturi ejector. The tank liquid is pumped continuously through the submerged ejector which has an air inlet pipe extending above the surface. The air and water are well mixed and clumps of bacterial cells are broken up. There is

less maintenance because the larger openings in the ejector do not clog as readily as do air diffusers of the types often used. Although the power costs are higher than those of conventional air diffusers, the efficiency and ease of operation recommend ejectors. Each unit of the type selected is capable of dissolving about 600 grams of oxygen per hour with a pumping rate of 1850 liters per minute through a 17-mm.-diameter nozzle.

In a typical plant, the waste enters the tank from 6:00 A. M. until 2.00 P. M. and is aerated throughout the day with the sludge remaining from the previous operation. At 2.30 P. M., the air supply is stopped, the sludge is allowed to settle for three hours, and the clear supernatant is drained off. Aeration is then resumed.

The amount of cells present is proportional to the concentration of milk solids in the waste, for cell synthesis must continue until it is balanced by amount of cells consumed by endogenous respiration. Calculations from the theoretical analysis show that the equilibrium cell weight in the system, at 30°C., is 2.5 times the average weight of milk solids received. This value has been confirmed in practice repeatedly.

These facts have permitted Professor Kountz to develop the essential design data if the amount of waste and concentration of solids are known. For a dairy plant handling 100,000 pounds of milk a day, with a small cottage cheese operation, the equivalent milk solids in the effluent might equal 2.5 per cent of the weight of milk received, or 2500 pounds. This waste might be dissolved in 25,000 gallons (200,000 pounds) of water.

The tank volume required would be 1½ times the average daily flow to allow for the sludge held over, variations in daily load, and to provide some height above the liquid at its highest level. The oxygen demand can be calculated on the known activity of the cells and the efficiency of the aerating device, thus establishing the number of aerators required.

In a commercial dairy treatment plan that approaches the hypothetical figures cited, Professor Kountz secured the following typical operating data.

### *Typical Operating Data*

Waste volume (8 hr.)	25,000 gal.
BOD of influent	1,660 ppm.
BOD of effluent	72 ppm.
BOD reduction	95.7%
Tank volume	37,500 gal.
Sludge volume	20-30%
Normal temperature	30°C
Dissolved oxygen	0.6-3.5 ppm.

Some large plants are on a 24-hour operation schedule. A fill-and-draw system is not applicable to them. Moreover, some regulatory agencies require discharge over the entire 24-hour period. A continuous flow system has been studied extensively at Pennsylvania State University and a number of installation are in successful operation. However, the aerated sludge is difficult to settle, especially during periods of rapid growth, and a completely satisfactory solution of this problem has not been reached. Further research on this phase and on more efficient means of aeration is planned. Cheese whey, which contains about 5 per cent organic solids, is a special problem in the field of waste treatment on which additional research is under way.

### REFERENCES

- (1) HOOVER S. R. and PORGES N.: Sewage and Ind. Wastes, 24, 306 (1952).
- (2) HOOVER S. R., JASEWICZ L. and PORGES N.: Sewage and Ind. Wastes, 24, 1144 (1952).
- (3) PORGES N., JASEWICZ L. and HOOVER S. R.: Applied Microbiology, 1: 262 (1953).
- (4) PORGES N., JASEWICZ L. and HOOVER S. R.: Proc. 9th Ind. Waste Conference, Purdue (in press).
- (5) KOUNTZ R. R.: Food Engineering, p. 89, October 1954.

### SUMMARY

Stream pollution by dairy wastes is a major problem of the dairy manufacturing industry in the United States. As a step toward the solution of this problem, a biochemical study was made of the oxidation of the dilute milk waste from dairy manufacturing plants by the mixed aerobic culture that develops naturally.

Determinations were made of the amount and chemical composition of the cell tissue produced, the amount of oxygen required, the effect of temperature, and the minimum concentration of dissolved oxygen required for a maximum rate of growth. Balanced equations were formulated for the growth of the organisms and their subsequent endogenous respiration (auto-oxidation).

These results were tested under two research contracts with Pennsylvania State University, in which pilot-plant engineering studies were made. The laboratory results were confirmed and extended. A novel, simple, « fill-and-draw » treatment system was proposed that is especially suitable for plants with a capacity less than 200.000 pounds of milk a day.

Nine commercial treatment plants have been built that are based directly on the recommended designs. These are the first industrial waste treatment plants that have been based on biochemical study and extensive engineering investigations. Many other installations have successfully applied the principles developed in these studies.

#### RESUME

### PROCEDES AEROBIQUES POUR LE TRAITEMENT DES EAUX RESIDUAIRES DES LAITERIES

La pollution des cours d'eau par les eaux résiduaires des laiteries pose un grand problème pour les industries laitières aux Etats-Unis. Un pas a été fait pour la solution de ce problème: une étude biochimique sur l'oxydation des eaux résiduaires diluées provenant des usines laitières, par la culture d'un mélange d'aérobies qui se développent naturellement. On a déterminé la quantité et la composition des tissus des cellules produites, la quantité d'oxygène requise, l'effet de la température et la concentration minimum de l'oxygène en solution nécessaire pour obtenir un taux maximum de croissance. On a établi les équations représentant le développement des microorganismes et leur respiration endogène (auto-oxydation).

Ces résultats furent expérimentés dans le cadre de deux contrats de recherches passés avec l'Université de l'Etat de Pennsylvanie, où des études techniques furent effectuées dans une installation-pilote.

Les résultats des laboratoires furent confirmés et approfondis. Un système nouveau et simple de traitement par « remplissage » et « pompage » fut proposé comme étant le mieux adapté pour des usines ayant une capacité de moins de 200.000 livres de lait par jour.

Neuf usines commerciales furent construites directement sur les bases de ces procédés. Celles-ci sont les premières réalisations de traitement des eaux résiduaires qui s'appuient sur des études biochimiques et des recherches techniques approfondies. Plusieurs autres installations ont appliqué avec succès les principes développés dans ces études.

#### ZUSAMMENFASSUNG

#### AEROBES VERFAHREN FÜR DIE BEHANDLUNG VON MOLKEREIABWASSER

Die Vermeidung der Verschmutzung von Wasserläufen durch Molkerei-Abwasser ist in den Ver. Staaten eine Frage von wesentlicher Bedeutung für das Molkereiwesen. Als ein Schritt zur Lösung des Problems wurde an Abfällen von verdünnter Milch aus Molkereibetrieben eine Untersuchung der Oxydationsvorgänge vorgenommen, die in diesen Abfällen durch das Auftreten von Mikroben hervorgerufen werden. Es wurden Menge und chemische Zusammensetzung des erzeugten Zellgewebes bestimmt, ferner die Menge des benötigten Sauerstoffs, der Einfluss der Temperatur und das Minimum der erforderlichen Sauerstoffkonzentration zur Erreichung einer maximalen Entwicklung. Es wurden Berechnungen aufgestellt für die Entwicklung der Mikroorganismen und ihre nachfolgende innere Atmung (Autoxidation).

Die Ergebnisse wurden in gemeinsamer Forschungsarbeit mit der Pennsylvania State University geprüft, wobei Untersuchungen in Versuchsanlagen durchgeführt wurden. Die Ergebnisse der Laboratoriumsarbeiten wurden dabei bestätigt und erweitert. Es wurde ein neues, einfaches Verfahren vorgeschlagen, das sich besonders für Anlagen mit einer Kapazität bis zu 200.000 lbs. Milch täglich eignet.

Auf Grund der Vorschläge wurden neun Anlagen auf kommerzieller Basis geschaffen. Das sind die ersten industriellen Anlagen zur Behandlung von Abfällen, die auf biochemischer Forschung und ausgehnten technischen Untersuchungen beruhen. Viele ande-re Unternehmungen haben seitdem die hier entwickelten Prinzipien mit Erfolg angewandt.

#### RESUMEN

#### PROCESO AEROBICO PARA EL TRATAMIENTO DE LOS DESPERDICIOS DE LECHERIA

La contaminación de los cursos de agua por los desperdicios de lechería es un problema importante de la industria lechera de los Estados Unidos. Con el fin de llegar a una solución de este problema, se ha efectuado un estudio bioquímico de la oxidación de los desperdicios diluidos de la leche procedentes de centrales de elaboración por el cultivo mixto aeróbico que se forma naturalmente. Se hicieron determinaciones de la cantidad y composición química del tejido celular producido, la cantidad de oxígeno necesaria, el efecto de la temperatura, y la concentración mínima de oxígeno disuelto que se precisa para un máximo ritmo de crecimiento. Se formularon ecuaciones equilibradas para el crecimiento de los organismos y su subsiguiente respiración endógena (auto-oxidación).

Estos resultados fueron sometidos a ensayo con dos contratos de investigación, con la Universidad del Estado de Pensilvania, en la que se efectuaron estudios de plantas experimentales. Los resultados de laboratorio se confirmaron y divulgaron. Se propuso un nuevo y sencillo sistema de « llenado y vaciado » especialmente adecuado para centrales con capacidad inferior a 200.000 libras de leche al día.

Se han construido nueve instalaciones de tratamiento comercial basadas directamente en los proyectos recomendados. Son éstas las primeras instalaciones industriales de tratamiento de los desperdicios, basadas en un estudio bioquímico y en investigaciones de ingeniería. Otras muchas instalaciones han aplicado con éxito los principios desarrollados en estos estudios.

## RIASSUNTO

### PROCEDIMENTO AEROBICO PER LA LAVORAZIONE DEI RIFIUTI DI LATTERIA

La contaminazione a flusso per mezzo di rifiuti di latteria è uno dei più grandi problemi dell'industria del latte e dei suoi prodotti negli Stati Uniti. Come primo passo verso la soluzione di tale problema è stato eseguito uno studio sull'ossidazione dei rifiuti del latte da consumo negli impianti di manifattura dei latticini con colture aerobiche miste che si sviluppano naturalmente. Furono stabilite: la quantità e la composizione chimica del tessuto cellulare prodotto, la quantità necessaria di ossigeno, gli effetti della temperatura, e concentrazione minima di ossigeno dissolto, richiesta per ottenere la massima crescita. Furono formulate equazioni equilibrate per la crescita degli organismi e la loro successiva respirazione endogena (auto-ossidazione).

I risultati anzidetti furono sottoposti a tests con due contratti di ricerca conclusi con l'Università dello Stato della Pennsylvania, in cui furono eseguiti anche studi sulla progettazione e la costruzione di impianti pilota. I risultati ottenuti in laboratorio furono confermati ed ampliati. Fu proposto un nuovo e semplice metodo « a riempimento e ritiro » (fill-and-draw-system), che è particolarmente adatto per quegli impianti la cui capacità non sorpassa le 200.000 libbre di latte al giorno.

Furono costruiti nove impianti per la lavorazione commerciale seguendo direttamente i progetti suggeriti. Questi sono i primi impianti industriali per la lavorazione dei rifiuti del latte che si basano sugli studi biochimici e sulle ricerche nel settore delle costruzioni. Molti altri impianti hanno poi seguito con successo i principi elaborati con tali studi.